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(71) Applicant: NEC CORPORATION
7-1, Shiba 5-chome
Minato-ku
Tokyo (JP)

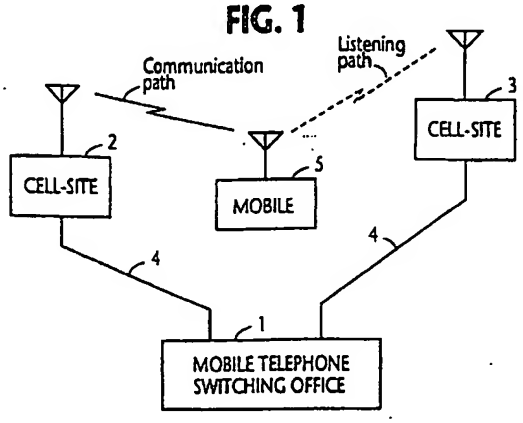
(72) Inventor: Otsuka, Shigeru, c/o NEC CORPORATION
7-1, Shiba 5-chome,
Minato-ku
Tokyo (JP)

(74) Representative: VOSSIUS & PARTNER
Siebertstrasse 4
D-81675 München (DE)

(54) Network synchronization for TDMA cellular communication using signals from mobile stations in neighboring cells.

(57) In a TDMA cellular communication network, one of the cell sites (2) is a reference station (2) for establishing a time reference in response to a timing signal from a mobile switching office (1), and each of the other cell sites (3) is a subordinate station (3). Each subordinate station (3) establishes a time slot in response to the timing signal from the mobile switching system and receives a signal from a mobile station (5) located in the area of the reference station (2) for detecting a time lapse between the time slot and the signal from the mobile station (5). A delay time is introduced to the time slot according to the time lapse so that the time slot is synchronized to the time reference of the reference station (2). In a second embodiment, each subordinate station (3) transmits a signal indicative of the detected time lapse to the mobile switching system, where a delay time value is derived from those signals received from a chain of subordinate stations (3) and returned to each subordinate station (3) for performing the time slot adjustment. The delay time value is a modulo τ summation of the time lapses received from such chain of subordinate stations (3), where τ is the duration of the time slot.

FIG. 1



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The present invention relates generally to network synchronization, and more specifically to synchronization for a TDMA (time division multiple access) cellular communication network.

According to a known synchronization technique for a digital cellular communication network, a reference cell site broadcasts a reference timing signal at periodic intervals over radio propagation paths using a dedicated transmitter or via respective land-lines. A plurality of subordinate cell sites are provided with a dedicated receiver for receiving the timing signal to adjust their slot timing. However, it is impossible to provide precision timing adjustment due to the inherent differences in length of the propagation paths and the land-lines.

It is therefore an object of the present invention to provide a network synchronization technique which no longer suffers from the prior art disadvantages.

According to a first aspect, the present invention provides a TDMA cellular communication network comprising a mobile switching system, and a plurality of cell site stations connected via respective paths to the mobile switching system for receiving a reference timing signal therefrom. One of the cell site stations is a reference station for establishing a time reference in response to the received reference timing signal, and each of the remainder cell site stations is a subordinate station. Each of the subordinate stations establishes a time slot in response to the reference timing signal from the mobile switching system and receives a signal from a mobile station which is located in the coverage area of the reference station and in communication with the reference station. The subordinate station detects a time lapse between the time slot and the signal from the mobile station, and introduces a delay time into the time slot according to the time lapse so that the delayed time slot is synchronized to the time reference of the reference station. This is particularly suitable and advantageous for a cluster of cell sites in which the reference station is at the center of the cluster bordering on each of the subordinate stations.

In a preferred embodiment, each subordinate station stores a plurality of values of the time lapse in a memory and derives an average value of time lapses from the stored values to introduce the average value of time lapses to the time slot.

According to a second aspect, each subordinate station transmits a signal indicative of the detected time lapse to the mobile switching system, where a delay time value is derived from the time lapse indicative signals which are received from a chain of the subordinate stations and transmitted to each subordinate station. On receiving the delay time value, each subordinate station introduces a delay time into the time slot so that it is synchronized to the time reference of the reference station. This is particularly suitable for a cluster of cell sites in which some of the cell sites are bordering on other subordinate stations of the same cluster.

The present invention will be described in further detail with reference to the accompanying drawings, in which:

Fig. 1 is a schematic block diagram of an exemplary cellular communication network in which the present invention is embodied;

Fig. 2 is a block diagram of a cell site which operates as a reference station;

Fig. 3 is a block diagram of a cell site which operates as a subordinate station;

Fig. 4 is a timing diagram useful for describing the operation of the first embodiment of the present invention;

Fig. 5 is an illustration of a typical example of cell patterns in which the first embodiment of the present invention will be used;

Fig. 6 is an illustration of a typical example of cell patterns in which the second embodiment of the present invention will be used;

Fig. 7 is a block diagram of each subordinate cell site station according to a second embodiment of the present invention;

Fig. 8 is a block diagram of the mobile telephone switching office according to the second embodiment of the present invention; and

Fig. 9 is a timing diagram useful for describing the operation of the second embodiment of the present invention.

An exemplary digital cellular communication network in which the present invention is embodied is illustrated in Fig. 1. The system in Fig. 1 utilizes TDMA modulation techniques in communication between mobile units and cell-site stations. In Fig. 1, a mobile telephone switching office **1**, connected to the public switched telephone network, not shown, typically includes interface and processing circuitry for providing system control to cell site stations **2** and **3** via coaxial cables **4** and providing routing control of telephone calls from the PSTN to the appropriate cell site station for transmission to the appropriate mobile unit and routing of calls from the mobile units via a cell site station to the PSTN. The MTSO may direct calls between mobile users via the appropriate cell site stations.

According to a first embodiment of the present invention, the cell site **2** operates as a reference station for establishing the reference slot timing for the network and the cell site **3** operates as a subordinate station for establishing its own slot timing based on the reference timing established by the cell site **2**.

As shown in Fig. 2, the cell site station **2** has, on the network side, a multiplexer/demultiplexer unit (MUX/DEMUX) **10** to transmit and receive digital signals of DS1 level (1.5-Mbps primary rate signal) to and from the MTSO via the coaxial cable **4** and a MUX/DEMUX unit **13**, on the mobile side, to transmit and receive TDMA frames (42 kbps) of three time

slots each to and from mobile units via diplexer **14** and antenna **15**. A control channel unit **11** and a plurality of traffic carrier units **12-1** through **12-N** are connected between the MUX/DEMUX units **10** and **13**.

MUX/DEMUX unit **10** decomposes the 1.5 Mbps DS1 signal into 24 channels of 64 kbps each. A DS1-frame sync detector **16** is connected to one of the outputs of MUX/DEMUX unit **10** to produce an output pulse in response to a frame sync that appears once for each DS1 frame comprising the 24 time slots. A controller **18** is connected to a serving cell-site slot memory **17** which stores busy/idle status of all traffic (speech) channels, or time slots of the cell site **2**.

Control channel unit **11** comprises a slot timing generator **20** which is responsive to the output of the frame sync detector **16** to produce timing pulses for transmit and receive control channels. These timing pulses are applied to a channel processor **24** and the transmit timing signal is also applied to a delay detector **21** and a timing advance message generator **22**. A sync detector **23** is connected to the channel process **24** to monitor a sync word contained in an uplink burst transmitted from a mobile unit and supplies an output signal to the delay detector **21** when the sync word is detected. Delay time detector **21** is activated by the transmit timing pulse from slot timing generator **20** to measure the length of time elapsed from the transmission of a downlink burst to a mobile unit to the arrival time of an uplink burst from the mobile unit so that the round trip time between the cell site and the mobile is determined. The output of the delay time detector **21** is applied to the timing advance message generator **22**.

For compensating for the varying distances between the cell site and mobile units, the timing advance message generator **20** translates the output of delay time detector **21** into a timing advance message which indicates the timing at which the mobile unit is to send an uplink burst. This timing advance message is supplied to the channel processor where it is multiplexed with each downlink burst to advance the timing of each mobile unit so that the data bursts transmitted by the mobile unit may fall exactly into the time slot structure at the cell site receiver. The channel processor **24** is connected at one end to appropriate terminals of the MUX/DEMUX unit **10** to exchange control signals with the MTSO **1** and connected at the other end to a radio transceiver **25** to communicate with a mobile unit initiating or receiving a call.

Each traffic carrier unit **12** includes a set of three speech coder/decoders, or codecs **30** connected to corresponding terminals of the MUX/DEMUX unit **10** and a set of corresponding channel codecs **31**. Each speech codec **30** translates the 64-Mbps digital incoming signal to a 11.2 kbps signal using data compression techniques such as a codebook-excited linear prediction speech coding algorithm. The 11.2-kbps output of each speech codec is applied to the corresponding channel codec **31** where forward error correction bits are inserted. Each traffic carrier unit further includes a slot-timing generator **34**, a timing advance message generator **37** and a delay time detector **35**. Slot-timing generator **34** is connected to the output of frame sync detector **16** to supply the transmit and receive slot timing signals to a MUX/DEMUX unit **32**. In order to amend the timing advance of each mobile unit during operation, the timing advance message generator **37** responds to an output of the delay time detector **35** for applying a renewed timing advance message to each channel codec. Delay time detector **35** determines the round trip time for each channel codec from the time difference between the output of frame sync detector **16** and a sync word which is detected by a sync word detector **36** in the data signal received by each channel codec **31**. The timing advance message data and other control bits are added in each channel codec to the 11.2 kbps output of each speech codec **30** to produce a 14 kbps signal which is multiplexed by the MUX/DEMUX unit **32** with the outputs of the other speech codecs to produce a 42 kbps output data stream. This data stream is modulated by a radio transceiver **33** upon the carrier of the particular frequency of the unit **12** and transmitted as a downlink TDMA frame to mobile units. An uplink data burst from a mobile unit is demultiplexed and demodulated by the transceiver **33** and fed into the appropriate channel codec **30** where the signal is converted to 11.2 kbps signal and applied to the corresponding speech codec where it is converted to a 64 kbps signal.

When a mobile unit **5** is located in the coverage area of cell site **2** and initiates a call, it sends a call request containing a sync word and a destination user address on the specified time slot to the cell site **2** where it is received by the channel processor **24** and relayed to the MTSO to allow it to establish a connection to a destination system user. The timing advance message generator **22** generates a timing advance message for the requesting mobile user. On the other hand, the channel processor **24** instructs the controller **18** to search the serving cell-site slot memory **17** for an idle speech channel and returns a control signal to the mobile unit, containing the identification of the idle speech channel and the timing advance message, to cause it to switch to the assigned speech channel. During communication, the distance between mobile unit **5** and cell site **2** may vary and hence the round trip delay varies accordingly. To compensate for the varying distance at intervals, the timing advance message generator **37** of the traffic carrier unit that is assigned to the mobile unit **5** to update its timing advance. Using the timing advance message, the mobile unit transmits an uplink burst containing a sync word during communication.

Fig 3 illustrates the details of cell site station 3. Cell site station 3 differs from cell site 2 by the inclu-

sion of a variable delay circuit **40**, a neighboring cell-site slot memory **41** and a delay time memory **42**. Variable delay circuit **40** is connected to the output of DS1-frame sync detector **16** to introduce an amount of delay determined by an output signal from the controller **18** into the reference timing signal supplied to all the slot timing generators **22** and **34**.

Controller **18** is associated with the neighboring cell-site slot memory **41** and delay time memory **42** as well as with the serving cell-site slot memory **17**. At intervals, controller **18** searches the speech channels of a neighboring cell site, i.e., cell site **2** to retune the transceiver **25** to listen to mobile units located in cell site **2** for adjusting the reference slot timing of the cell site **3** with respect to the reference timing of cell site **2**. This is accomplished as follows. Variable delay circuit **40** is initially adjusted to zero setting and slot timing generator **20** at cell site **3** is triggered in response to each output of frame sync detector **16** to provide a timing signal at slot intervals to delay detector **21**. Transceiver **25** is retuned to receive an uplink burst from a mobile unit in a neighboring cell to allow sync detector **23** to detect a sync word contained in the received uplink burst. The delay time detector **21** produces an output indicating the time difference between the most recent slot timing and the reception of the uplink burst from the neighboring cell site mobile.

The operation of the cell site stations **2** and **3** will be best understood with the following description given with reference to Fig. 4 by assuming that the mobile unit **5** is in communication with a system user via the cell site **2**.

Mobile telephone switching office **1** sends 1.5 Mbps signals synchronized to the same time base to the cell site stations **2** and **3** and a frame sync contained in each of these 1.5 Mbps signals is indicated by numeral **40**. At cell sites **2** and **3**, the frame sync **40** is received at different times as indicated at **41** and **42**, respectively, so that there is a time difference D_0 between cell sites **2** and **3** corresponding to the difference between the lengths of their cables **4** to the MTSO **1**. At cell site **2**, a downlink TDMA frame **43T** is transmitted and a downlink burst to the mobile unit **5** is carried on time slot T1 of the frame and received as by mobile unit **5** as indicated at **44R**. A timing advance message is multiplexed on time slot T1 of the TDMA frame **43T** to cause mobile unit **5** to transmit an uplink burst **44T** so that the latter exactly falls into the receive slot R1 of the downlink TDMA frame **43R** of cell site **2**.

At cell site **3**, on the other hand, the controller **18** makes a search through the neighboring cell-site slot memory **41** at intervals when it is free from the call processing tasks of cell site **3**, and listens to mobile unit **5** by retuning the transceiver **25** according to the slot data in memory **41**. As a result, the uplink burst **44T** from mobile unit **5** is received a delay time D_1 after the most recent slot timing pulse **45** generated by the slot timing generator **20**. The delay time D_1 is detected by the detector **21** and supplied to controller **18**. Controller **18** stores the delay time value into delay time memory **42**. In this way, several delay time values may be derived from mobile units in different locations and stored in memory **42**. Controller **18** seeks an average value of the stored delay times and sets the average delay time value into the variable delay circuit **40**. As a result, the slot timing of cell site **3** is delayed by an amount corresponding to the delay time D_1 as indicated by numeral **46**. Therefore, the slot timing of cell site **3** is aligned with the slot timing of cell site **2**. If mobile unit **5** crosses the boundary between cell sites **2** and **3**, an uplink burst from mobile unit **5** can be received correctly during a receive slot of cell site **3** and a handoff operation can be smoothly performed.

Fig. 5 illustrates one example of cell patterns in which the first embodiment of the present invention can be used. The reference cell site station **2** is located at the center of a seven cell cluster configuration surrounded by six subordinate cell site stations **3A** to **3F**. Since the same pattern can be repeated, the first embodiment of the present invention can be employed in a wider service area. If the number of cell sites in a cluster is more than seven as indicated in Fig. 6 where additional subordinate cell sites **3G** to **3M** are provided on the outer area of a cluster, such outer cell sites will listen to mobiles located in the inner cells of subordinate stations. Since the inner subordinate cell sites listen to mobile units in the cell of reference station **2**, the introduction of delay times to these cell sites must be coordinated.

Fig. 7 is a block diagram of each subordinate cell sites according to a second embodiment of the present invention, and Fig. 8 is a block diagram of the MTSO that provides the coordination of the delay times.

The cell site station shown in Fig. 7 differs from the Fig. 3 embodiment in that the delay time memory **42** is dispensed with and a delay setting circuit **60** is provided to respond to a command signal from the MTSO. In addition, the transceiver **25** is retuned during an idle period by controller **18** to listen to a mobile unit in a neighboring cell to allow the delay time detector **21** to detect a delay time of the mobile's signal with respect to the most recent slot timing pulse produced by slot-timing generator **20**. This delay time of each subordinate cell site is applied to the controller **18** and supplied to the channel processor **24** and transmitted to the MTSO **1** together with the identification of the cell site. The neighboring cell-site slot memory **41** of each subordinate cell site holds the speech channel frequency data of a predetermined neighboring cell site with which it borders. For example, cell site **3B** holds the frequency data of reference cell site **2**, cell site **3J** holds the frequency data of cell

site 3B, and cell site 3M stores the frequency data of cell site 3J. The MTSO 1 knows in advance the delay time relationships among all the subordinate cell sites.

As illustrated in Fig. 8, the MTSO 1 includes a digital switching system 70 which establishes connections between the public switched telephone network, not shown, and an interface 71 to which are connected MUX/DEMUX units 72 and 73 for multiplexing the outputs of interface 71 into downlink 1.5-Mbps primary rate signals bound for cell sites 2 and 3 and demultiplexing uplink 1.5-Mbps primary rate signals from the cell sites into 64-kbps signals to be switched through the switching system 70.

A delay time memory 74 is connected to the interface 71 to store the delay time data transmitted from all subordinate cell sites. A delay time computing unit 75 is connected to the memory 74 to read the collected delay time values from the memory 74 in response to a periodic timing pulse from a timebase 76 and compute the necessary delay times to be introduced to the subordinate cell sites. The computed delay time data are supplied to a delay setting message generator 77 where it is assembled with a cell-site identity code and fed to the interface 71.

At each subordinate cell site, the delay time data from the MTSO is received by the delay setting circuit 60 to set into the variable delay circuit 40 to introduce a particular value of delay time into the reference pulse of the cell site from frame sync detector 16.

Computing unit 75 provides modulo-τ summation of successive delay time values transmitted from a chain of cell sites (where τ is the duration of a time slot), say, a first chain of cell sites 3B and 3J to compute data for cell site 3J and a second chain of cell sites 3B, 3J and 3M for computing data for cell site 3M. However, no computations are necessary for those cell sites that border the reference cell site 2 since the delay time values received from these cell sites represent the same value of delays to be introduced in these cell sites. These delay time values are only used for determining the delay time values of adjacent cell sites and simply returned to the delay setting circuit 60 of the source cell sites or a command signal may be sent to these cell sites to set the variable delay 40 to the value of delay times transmitted.

For example, the delay time value for cell site 3J is computed by summing the delay time values from cell sites 3B and 3J to produce a sum. If the sum exceeds an integral multiple of time duration τ, the amount of delay that exceeds the integral multiple of τ is the desired delay time. Likewise, the delay time value for cell site 3M is computed by summing the delay time values from cell sites 3B, 3J and 3M to produce a second sum. If the second sum exceeds an integral multiple of time duration τ, then the amount of delay that exceeds the integral multiple of τ is the desired delay time.

The operation of the second embodiment of the present invention will be better understood with reference to a timing diagram shown in Fig. 9 by assuming that, in response to a frame sync 80 from the MTSO, reference pulses 81, 82, 83 and 84, are produced respectively in succession at cell sites 2, 3B, 3J and 3M with a first time difference D_0 between pulses 81 and 82, a second time difference D_2 between pulses 82 and 83, and a third time difference D_2 between pulses 83 and 84. In response to reference pulses 81, 82, 83 and 84, downlink TDMA frames 85, 86, 87 and 88 are transmitted from cell sites 2, 3B, 3J and 3M, respectively. A mobile user in the cell site 2 area will receive the TDMA frame 85 in a slot 89 and send an uplink burst 90 which will received by cell site 3B a delay time D_3 following the slot timing 91 of TDMA frame 86. In a similar manner, a mobile station in the cell site 3B area will receive the TDMA frame 86 in a slot 92 and send an uplink burst 93 which will received by cell site 3J a delay time D_4 following the slot timing 94 of TDMA frame 87. A mobile station in the cell site 3J area will receive the TDMA frame 87 in a slot 95 and send an uplink burst 96 which will received by cell site 3M a delay time D_5 following the slot timing 97 of TDMA frame 88.

The delay time data D_3, D_4 and D_5 are sent to the MTSO from cell sites 3B, 3J and 3M, respectively, where computations are performed to obtain delay time values $D_6 = (D_3 + D_4)$ modulo τ and $D_7 = (D_3 + D_4 + D_5)$ modulo τ. The MTSO sends the delay time values D_6 and D_7 to cell sites 3J and 3M, respectively, where the variable delay circuit 40 are set to introduce these values to the reference timing pulse. On the other hand, the cell site 3B is commanded to set the delay time D_3 into the variable delay circuit 40. In this way, the reference timing pulses of cell sites 2, 3B, 3J and 3M are all synchronized to each other.

Claims

1. A TDMA (time division multiple access) cellular communication network comprising:

   a mobile switching system;

   a plurality of cell site stations connected via respective paths to said mobile switching system for receiving a reference timing signal therefrom, each of the cell site stations serving mobile stations located in a coverage area, one of said cell site stations being a reference station for establishing a time reference in response to the received reference timing signal, each of the remainder cell site stations being a subordinate station which comprises:

   slot timing means for establishing a time slot in response to the reference timing signal received from the mobile switching system;

   monitor means for receiving a signal from

a mobile station which is located in the coverage area of said reference station and in communication with said reference station and detecting a time lapse between said time slot and the signal from said mobile station; and

variable delay means for introducing a delay time into said time slot according to said time lapse so that the delayed time slot is synchronized to the time reference of said reference station.

2. A TDMA cellular communication network as claimed in claim 1, wherein each of said subordinate stations further comprises:

a memory for storing a plurality of values of said time lapse; and

means for deriving an average value of time lapses from the stored plurality of values for causing said delay introducing means to introduce the average value of time lapses.

3. A TDMA cellular communication network as claimed in claim 1 or 2, wherein said monitor means comprises:

a radio frequency receiver;

a memory for storing data concerning communication channels of said reference station; and

means for successively reading stored communication channel data from the memory and tuning said radio frequency receiver according to the read channel data.

4. A TDMA cellular communication network as claimed in any of claims 1 to 3, wherein said reference station is located in a central position of a cluster of said cell site stations bordering on each of said subordinate stations.

5. A TDMA (time division multiple access) cellular communication network comprising:

a mobile switching system;

a plurality of cell site stations connected via respective paths to said mobile switching system for receiving a reference timing signal therefrom, each of the cell site stations serving mobile stations located in a coverage area, one of said cell site stations being a reference station for establishing a time reference in response to the received reference timing signal, each of the remainder cell site stations being a subordinate station which comprises:

slot timing means for establishing a time slot in response to the reference timing signal received from the mobile switching system;

monitor means for receiving a signal from a mobile station which is located in the coverage area of said reference station and in communication with said reference station and detecting a time lapse between said time slot and the signal from said mobile station;

means for transmitting a signal indicative of the detected time lapse to said mobile switching system; and

variable delay means for introducing a delay time into said time slot according to a delay time value received from the mobile switching system so that the delayed time slot is synchronized to the time reference of said reference station,

said mobile switching system comprising:

means for receiving the time lapse indicative signal from each of said subordinate stations; and

means for deriving said delay time value from the time lapse indicative signals received from a chain of said subordinate stations and transmitting said delay time value to each of said subordinate stations.

6. A TDMA cellular communication network as claimed in claim 5, wherein said delay time value is a modulo τ summation of the time lapses indicated by the signals received from said chain of subordinate stations, where τ is the duration of said time slot.

7. A TDMA cellular communication network as claimed in claim 5 or 6, wherein said monitor means comprises:

a radio frequency receiver;

a memory for storing data concerning communication channels of said reference station; and

means for successively reading stored communication channel data from the memory and tuning said radio frequency receiver according to the read channel data.

8. A TDMA cellular communication network as claimed in any of claims 1 to 4, wherein said reference station comprises means for transmitting a downlink TDMA frame to mobile stations and receiving uplink bursts in respective time slots of an uplink TDMA from the mobile stations and a timing advance message to each of said mobile stations for allowing the mobile station to transmit an uplink burst so that the transmitted uplink burst is received during a time slot of the reference station, and wherein the monitor means of the subordinate station includes means for receiving the uplink burst and deriving said time lapse from the received uplink burst and the reference timing signal received from the mobile switching system.

9. A TDMA cellular communication network as claimed in any of claims 5 to 7, wherein said reference station comprises means for transmitting a downlink TDMA frame to mobile stations and receiving uplink bursts in respective time slots of an uplink TDMA from the mobile stations and a timing advance message to each of said mobile stations for allowing the mobile station to transmit an uplink burst so that the transmitted uplink burst is received during a time slot of the reference station, and wherein the monitor means of the subordinate station includes means for receiving the uplink burst and deriving said time lapse from the received uplink burst and the reference timing signal received from the mobile switching system.

10. A method of synchronizing the time reference of cell site stations in a TDMA (time division multiple access) cellular communication network, each of the cell site stations serving mobile stations located in a coverage area, one of said cell site stations being a reference station for establishing a timing reference in response to the received reference timing signal, each of the remainder cell site stations being a subordinate station, the method comprising the steps of:

at each of said cell site stations, receiving a reference timing signal from a mobile switching system and establishing a time slot therefrom;

at each of said subordinate stations, receiving a signal from a mobile station which is located in the coverage area of said reference station and in communication with said reference station;

detecting a time lapse between said time slot and said signal from the mobile station; and

introducing a delay time into said time slot according to said time lapse so that the delayed time slot is synchronized to the time reference of said reference station.

11. A method of synchronizing the time reference of cell site stations in a TDMA (time division multiple access) cellular communication network, each of the cell site stations serving mobile stations located in a coverage area, one of said cell site stations being a reference station for establishing a timing reference in response to the received reference timing signal, each of the remainder cell site stations being a subordinate station, said cell site stations being connected via respective paths to a mobile switching system for receiving a reference timing signal therefrom and establishing a time slot from the received reference timing signal, each of the cell site stations serving mobile stations located in a coverage area, one of said cell site stations being a reference station for establishing a time reference in response to the received reference timing signal, each of the remainder cell site stations being a subordinate station, the method comprising the steps of:

at each of said subordinate stations, receiving a signal from a mobile station which is located in the coverage area of said reference station and in communication with said reference station and detecting a time lapse between said time slot and the signal from said mobile station;

transmitting a signal indicative of the detected time lapse from the subordinate station to said mobile switching system;

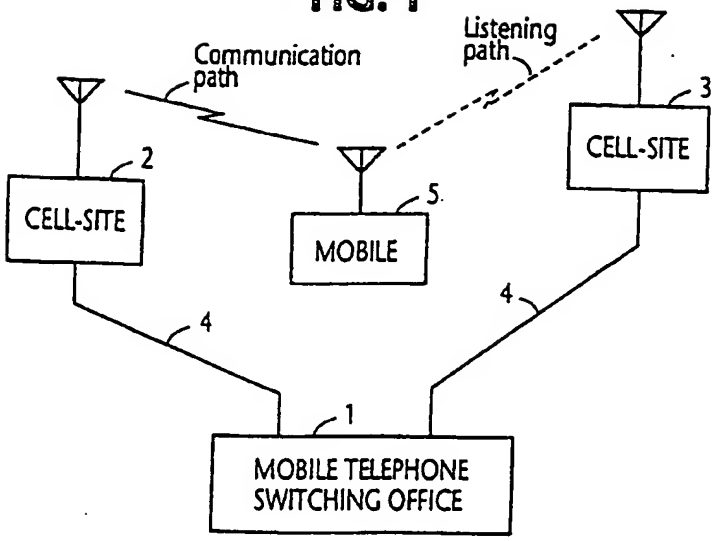
at said mobile switching system, receiving the time lapse indicative signal from each of said subordinate stations; and

deriving a delay time value from the time lapse indicative signals received from a chain of said subordinate stations and transmitting a signal indicative of said delay time value to each of said subordinate stations; and

at each of said subordinate stations, receiving said delay time value indicative signal from the mobile switching system and introducing a delay indicative signal from the mobile switching system and introducing a delay time into said time slot according to the delay time value of the received signal so that the delayed time slot is synchronized to the time reference of said reference station.

12. A method as claimed in claim 11, wherein said delay time value is a modulo τ summation of the time lapses indicated by the signals received from said chain of subordinate stations, where τ is the duration of said time slot.

FIG. 1


Communication path
Listening path
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CELL-SITE
3
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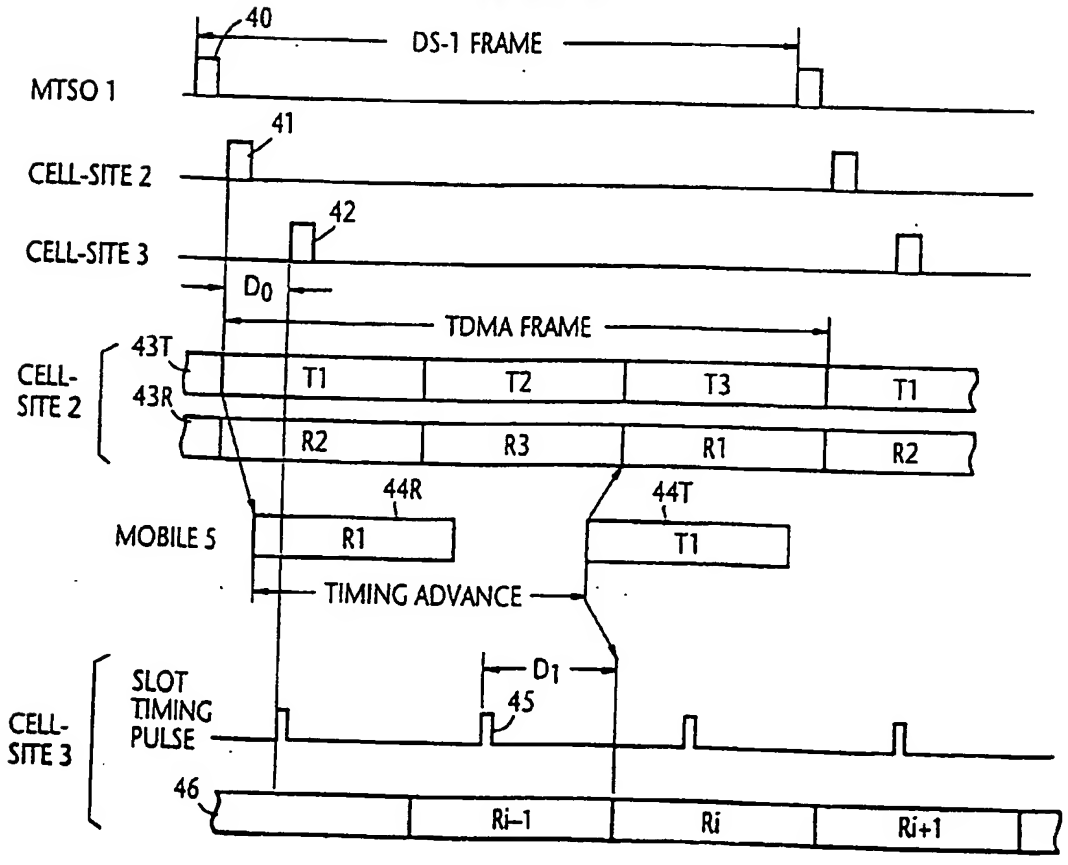
MOBILE TELEPHONE SWITCHING OFFICE

FIG. 4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T1
T2
T3
T1
R2
R3
R1
R2
44R
44T
MOBILE 5
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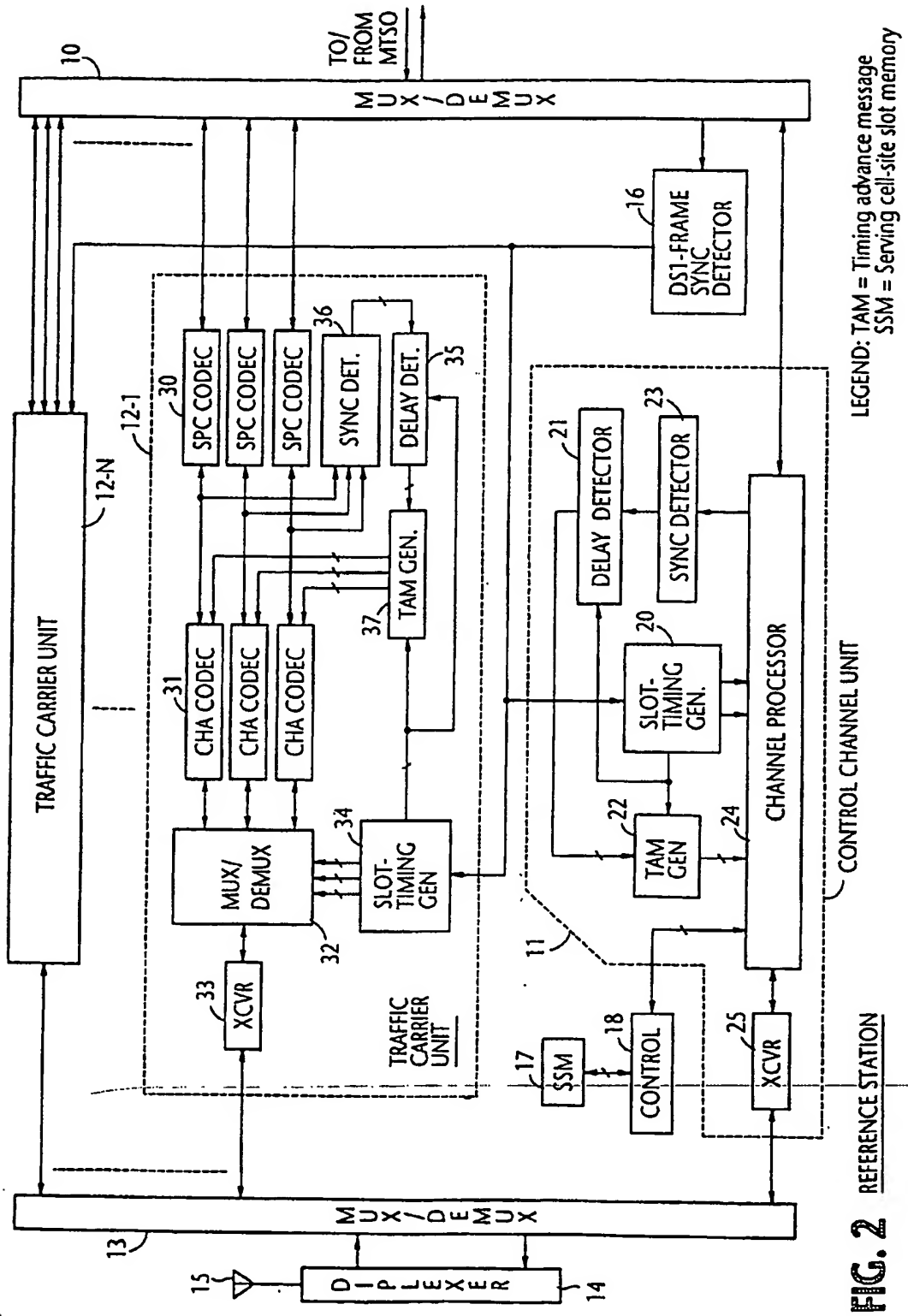
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SPC CODEC
SPC CODEC
SPC CODEC
SYNC DET.
DELAY DET.
30
36
35
TAM GEN.
37
CHA CODEC
CHA CODEC
CHA CODEC
31
MUX/ DEMUX
34
SLOT-TIMING GEN
32
XCVR
33
TRAFFIC CARRIER UNIT
DELAY DETECTOR
SYNC DETECTOR
21
23
SLOT-TIMING GEN.
20
TAM GEN
22
24
CHANNEL PROCESSOR
CONTROL CHANNEL UNIT
11
SSM
17
CONTROL
18
XCVR
25
MUX/DEMUX
13
DIPLEXER
15
14
LEGEND: TAM = Timing advance message
SSM = Serving cell-site slot memory
REFERENCE STATION

FIG. 2

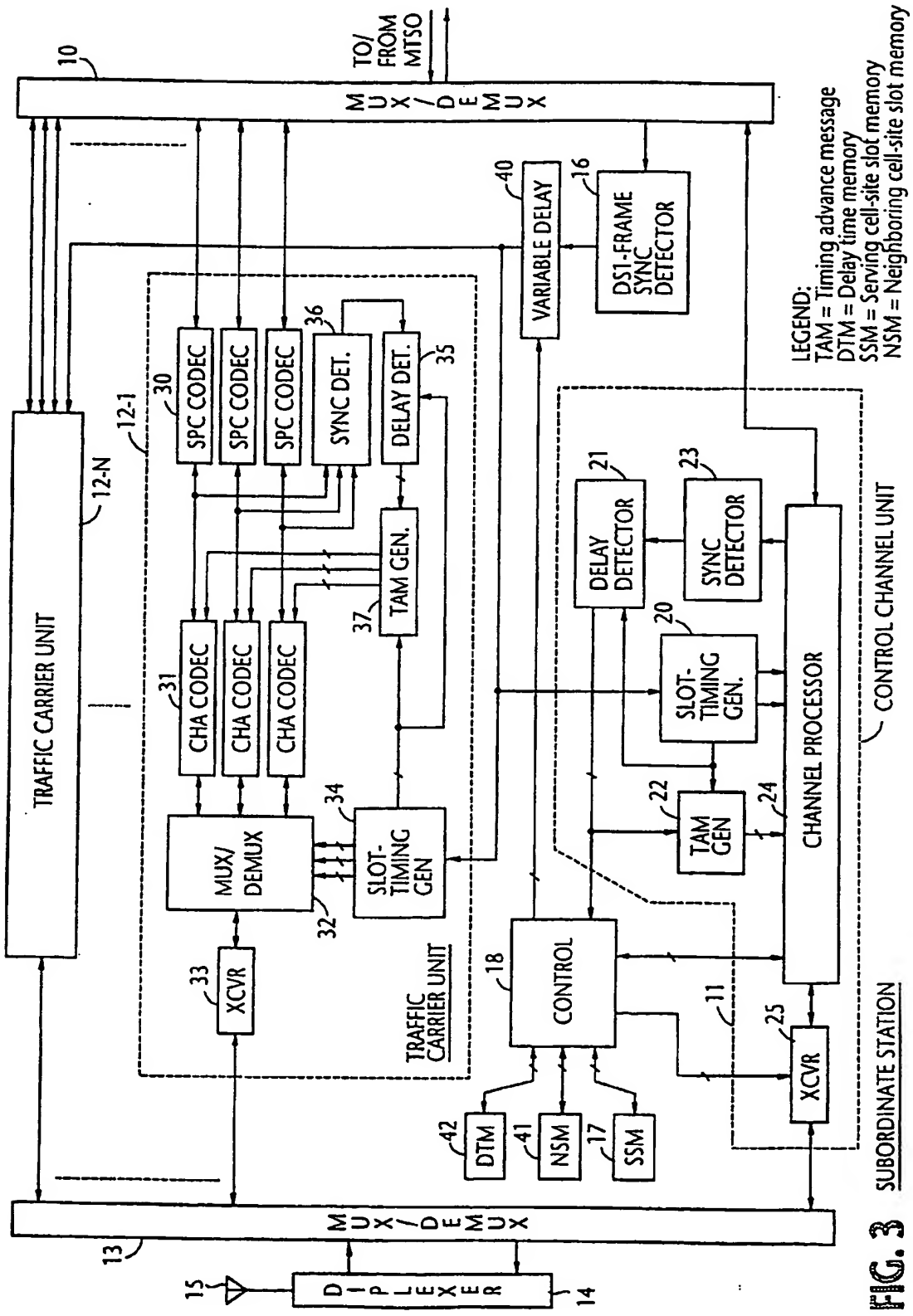

TO/ FROM MTSO
MUX/DEMUX
10
VARIABLE DELAY
40
DS1-FRAME SYNC DETECTOR
16
LEGEND:
TAM = Timing advance message
DTM = Delay time memory
SSM = Serving cell-site slot memory
NSM = Neighboring cell-site slot memory
TRAFFIC CARRIER UNIT
12-1
12-N
SPC CODEC
SPC CODEC
SPC CODEC
SYNC DET.
DELAY DET.
30
36
35
TAM GEN.
37
CHA CODEC
CHA CODEC
CHA CODEC
31
MUX/ DEMUX
SLOT-TIMING GEN
34
32
XCVR
33
TRAFFIC CARRIER UNIT
DELAY DETECTOR
21
SYNC DETECTOR
23
SLOT-TIMING GEN.
20
TAM GEN
22
CHANNEL PROCESSOR
24
CONTROL CHANNEL UNIT
CONTROL
18
11
XCVR
25
DTM
42
NSM
41
SSM
17
MUX/DEMUX
13
DIPLEXER
15
14
SUBORDINATE STATION

FIG. 3

FIG. 5

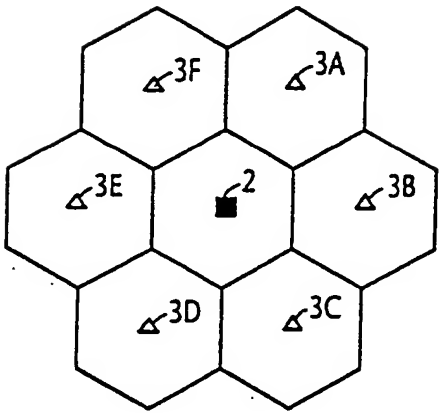
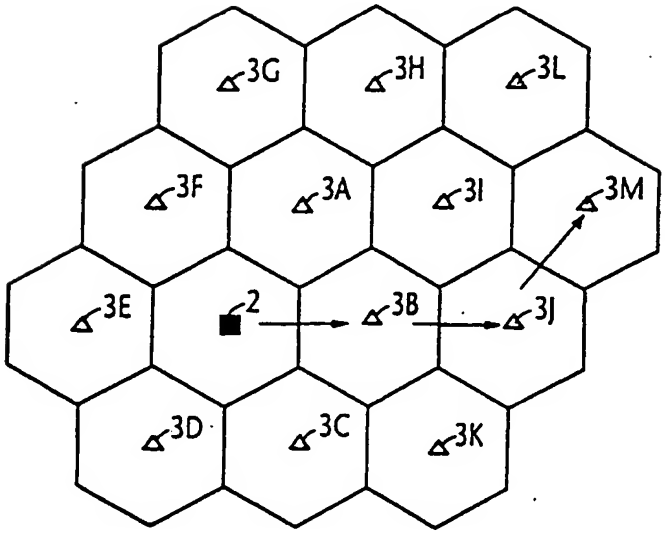


FIG. 6



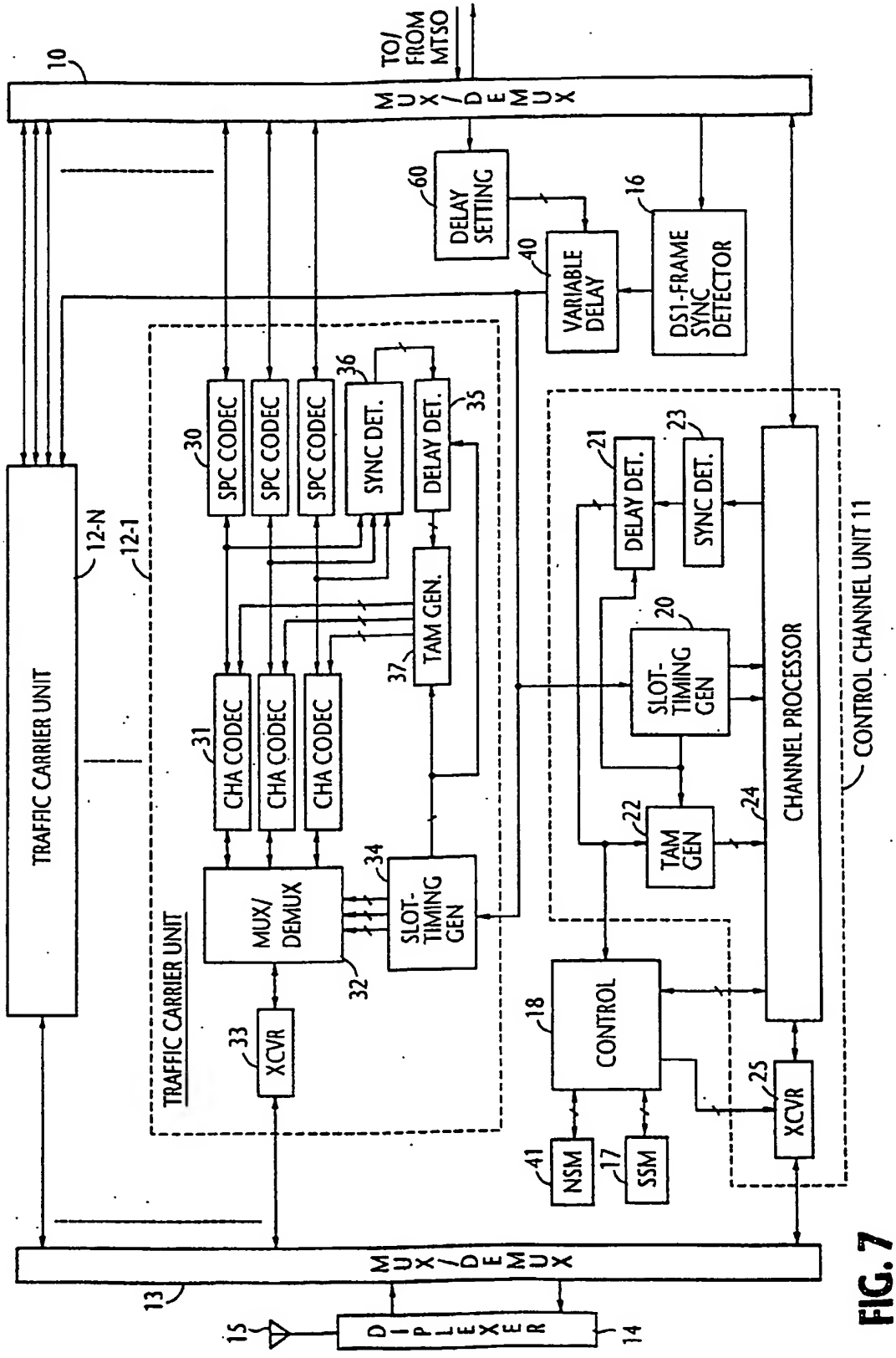

TO/
FROM
MTSO
MUX/DEMUX
10
DELAY
SETTING
60
VARIABLE
DELAY
40
DS1-FRAME
SYNC
DETECTOR
16
TRAFFIC CARRIER UNIT
12-N
12-1
SPC CODEC
SPC CODEC
SPC CODEC
30
SYNC DET.
36
DELAY DET.
35
TAM GEN.
37
CHA CODEC
CHA CODEC
CHA CODEC
31
MUX/
DEMUX
34
SLOT-
TIMING
GEN
32
XCVR
33
TRAFFIC CARRIER UNIT
DELAY DET.
21
SYNC DET.
23
SLOT-
TIMING
GEN
20
TAM
GEN
22
24
CHANNEL PROCESSOR
CONTROL CHANNEL UNIT 11
CONTROL
18
NSM
41
SSM
17
XCVR
25
MUX/DEMUX
13
DIPLEXER
15
14

FIG. 7

FIG. 8

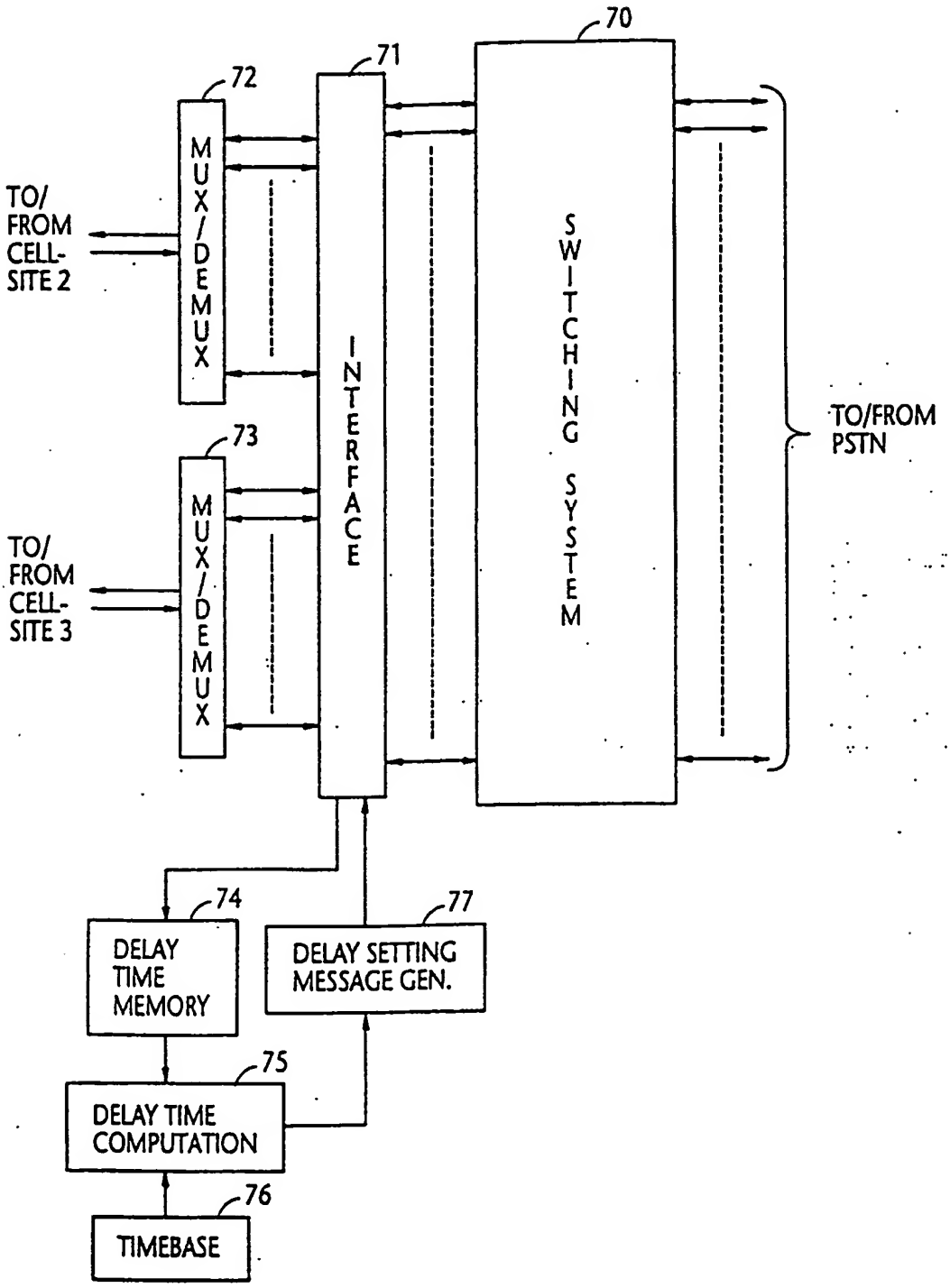
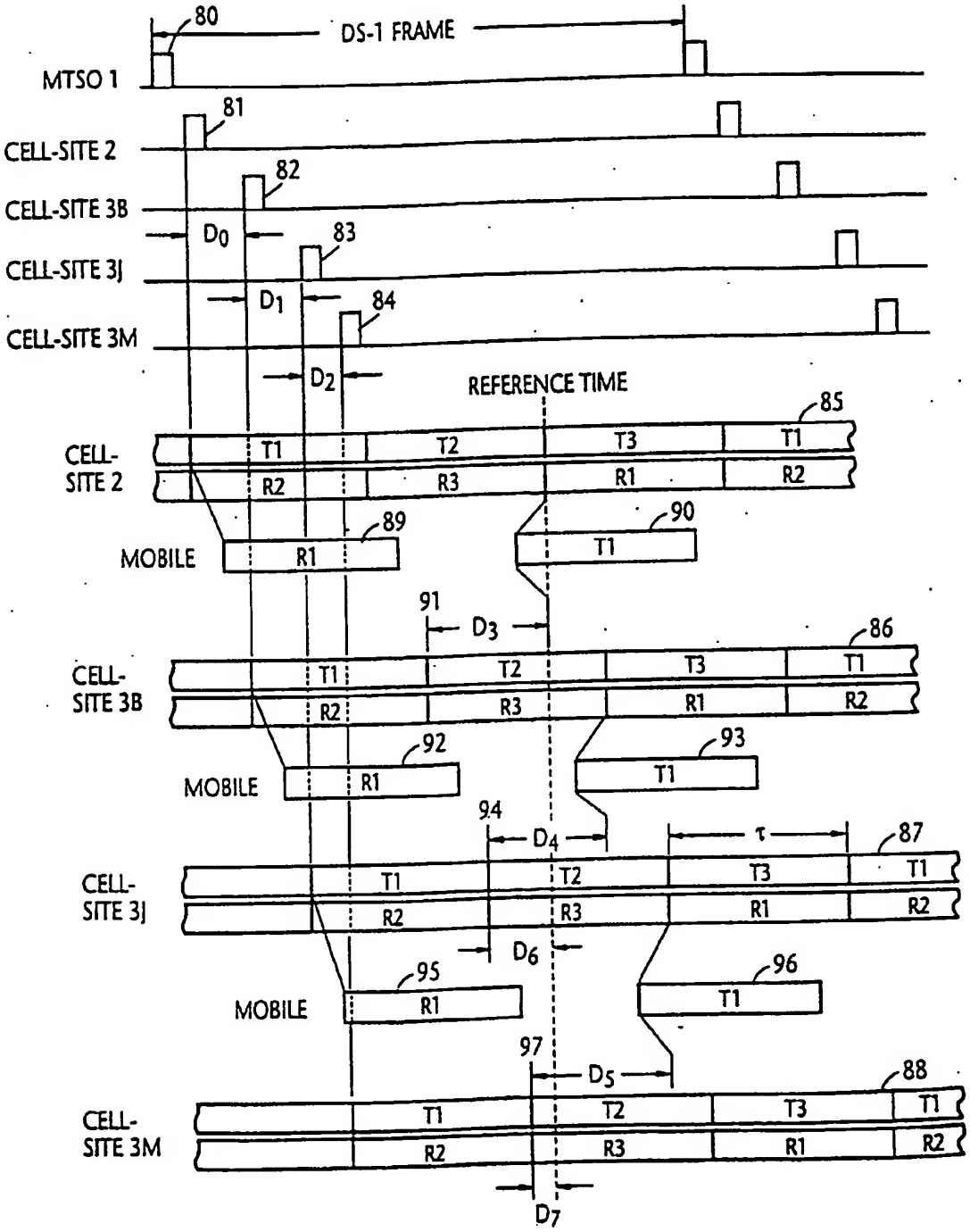

70
71
72
73
74
75
76
77
MUX/DEMUX
MUX/DEMUX
INTERFACE
SWITCHING SYSTEM
TO/FROM CELL-SITE 2
TO/FROM CELL-SITE 3
TO/FROM PSTN
DELAY TIME MEMORY
DELAY SETTING MESSAGE GEN.
DELAY TIME COMPUTATION
TIMEBASE

FIG. 9


80
DS-1 FRAME
MTSO 1
81
CELL-SITE 2
82
CELL-SITE 3B
D0
83
CELL-SITE 3J
D1
84
CELL-SITE 3M
D2
REFERENCE TIME
85
CELL-SITE 2
T1
T2
T3
T1
R2
R3
R1
R2
89
MOBILE
R1
90
T1
91
D3
86
CELL-SITE 3B
T1
T2
T3
T1
R2
R3
R1
R2
92
MOBILE
R1
93
T1
94
D4
τ
87
CELL-SITE 3J
T1
T2
T3
T1
R2
R3
R1
R2
D6
95
MOBILE
R1
96
T1
97
D5
88
CELL-SITE 3M
T1
T2
T3
T1
R2
R3
R1
R2
D7

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